VERSION WITH MARKINGS TO SHOW CHANGES MADE

~~KOHLER SCHMID + PARTNERS~~METHOD AND APPARATUS FOR MEASURING BENT WORKPIECES

~~PATENT ATTORNEYS~~

~~25.778 SI/nu~~

~~Trumpf Werkzeugmaschinen~~

~~GmbH + Co. KG~~

~~Johann-Maus-Strasse 2~~

~~D-71254 Ditzingen~~

~~Mechanical Bending Device and Mechanical Arrangement with this Type of Bending Device~~

~~The invention concerns a mechanical bending device for bending flat workpieces, especially sheet metal, with at least one bending tool, which has at least one part that can be moved by means of a drive, whereby the workpiece can be bent along a bending line when acted on by the moving tool part, and the moveable tool part contains segments, one after another, in the direction of the bending line. The invention also concerns a mechanical arrangement with the bending device described above.~~

~~The generic state of the art is document DE 196 40 124 A1. This prior publication discloses a bending machine with a swivel bending tool. A bending cheek of the swivel bending tool is provided with a bending cheek tool, which is in turn composed of tool sections arranged in a row in the direction of the bending line. Individual tool sections can be moved back and forth between the on and off positions. If the tool sections are in the on position, they act on the workpiece when the bending cheeks swivel and thus help~~

~~bend it. When they go into the off position, the tool sections pass by the workpiece without deforming it. For tooling, the bending cheek is always swiveled with all tool sections, i.e., those in the on and off positions.~~

~~This invention is designed to advance the state of the art by making improved adjustment to changing applications possible.~~

~~The invention solves the problem with the mechanical bending device in Patent Claim 1 and the mechanical arrangement in Patent Claim 10.~~

~~In the case of the invention, at least one segment of the tool part is used which can be connected optionally to the bending drive. When the workpiece is being formed, the only segments of the tool part that are moved are those that are actually needed to produce the desired bend. The other segments of the tool part can stay in the resting position. The right bending tool is therefore available for each bending cycle and no tool change has is necessary.~~

~~Special embodiments of the invention are described in dependent patent claims 2 to 9.~~

~~In the design of the invention in Patent Claim 2, the bending tool swivels and has cheek segments that can be driven, if necessary. The advantage of using the swiveling bending tool in the invention is that only the curved workpiece arm leaves its starting position when the workpiece is being tooled. The rest of the workpiece can stay in its initial position during the tooling process, unlike press braking, for example.~~

~~In the interest of an effective, easy to build means of introducing the bending force needed for tooling the workpiece, the bending device in Claim 3 of the invention is built~~

~~with at least one segment of the bending cheek as a two arm swiveling lever with a bending arm and a drive arm.~~

~~The designs in Patent Claims 4 to 6 of the invention provide structurally easy-to-change ways of optionally making or breaking the drive connection between the movable segments of the tool part of the bending tool and the bending drive.~~

~~In another advantageous embodiment of the invention, according to Patent Claim 7, not only is the part of the tool that can move when the workpiece is being formed divided into segments, but so is the holding down device assigned to that tool part. The segments of the holding down device can optionally be connected to the drive of the holding down device. A connection with the accompanying drive is made for those segments of the holding down device and the bending cheeks that work together when a workpiece is being tooled. Accordingly, the workpiece is acted on by the holding down device or segments of the holding down device only in the area where the desired bend is to be made. Segments of the holding down device arranged in other, roughly adjacent areas of the workpiece can be kept away from the workpiece. This possibility is a special advantage if a bend must be made close to a bend that already exists on the workpiece. If the action of the workpiece with the segments of the holding down device is limited to the area of the workpiece with the additional bend, then unwanted deformation of the already existing bend is prevented by the segments of the holding down device.~~

~~The model of the invention in Patent Claim 8 has the option of making bends in opposite directions on the workpiece being tooled. In the interest of a compact, inexpensive design, Patent Claim 9 provides that the drive of one bending tool and the drive of the holding down device of the other bending tool have at least one drive element in common, at least on one side of the workpiece being tooled.~~

~~The invention will be explained in greater detail below with examples and highly schematic drawings.~~

~~Figure 1~~ ~~shows a bending machine for machine bending a piece of sheet metal~~

~~Figures 2 to 6~~ ~~show the sequence of a bending cycle using the operating states produced thereby for a bending tool that can be used on the first type of bending machine in Figure 1.~~

~~Figures 7a to 7d and 8a to 8d~~ ~~show how the second type of bending tool works on the bending machine in Figure 1,~~

~~Figure 9~~ ~~shows a double tool that can be used on the bending machine in Figure 1 and~~

~~Figure 10~~ ~~shows a mechanical arrangement for machining sheet metal with a bending and a cutting station.~~

~~According to Figure 1, a bending machine 1 has a C-shaped frame 2 with a top arm 3 and a bottom arm 4. A conventional coordinate guide 5 is placed in the space on the bending machine 1 between the top arm 3 and the bottom arm 4 of the frame. A workpiece to be machined in the form of a piece of sheet metal 6 is held on the coordinate guide 5 by means of clips, not shown, and can move with the corresponding movement of the coordinate guide 5 in the horizontal plane of the sheet metal. When it~~

~~is moved by the coordinate guide 5, the sheet metal 6 rests on a workpiece table 7 of the usual kind placed on top of the bottom arm 4.~~

~~The purpose of moving the sheet metal 6 with the coordinate guide 5 is to position it opposite a mechanical bending device in the form of a bending station 8 on the free end of the top arm 3. At bending station 8, folds 10 of different lengths are made along the bending lines 11 with a bending tool 9. Folded grooves 12 were cut free on three sides of the flat sheet metal 6 in the tooling cycle before the sheet metal 6 is bent. Grooves 13 still lying in the plane of the sheet metal 6 are also shown in Figure 1. The folding of one of these grooves 13 along a bending line 11 will be described below.~~

~~Figures 2 to 6 show the bending tool 9 as a swiveling bending tool with a bending cheek 14, a holding down device 15 and a workpiece support 16. The bending cheek 14 is composed of five segments of bending cheeks 17, and the holding down device 15 is composed of five segments of holding down device 18. Both the segments of the bending cheeks 17 and the segments of the holding down device 18 are lined up in a row in the direction of the bending line 11 defined by bending cheek 14 and work with holding down device 15.~~

~~The segments of the bending cheeks 17 are designed as swiveling levers, and each has a bending arm 19 and a drive arm 20. They are mounted so they can swivel on a swivel axis 21 on a bending cheek holder 22 of bending station 8. The drive arms 20 are supported with their free ends on a control path 23, which is provided in turn on a control element 24. The control elements 24 can move in a straight line on the bending cheek holder 22. The control elements 24 can be connected to the piston 25 of a bending drive 27 via couplings 25. An individual coupling 25 is assigned to each control element 24. The couplings 25 can be engaged or disengaged by means of regulating devices, not shown, individually between the control elements 24 and the piston 26 of the bending~~

~~drive 27. Alternately, the control elements 24 and the piston 26 of the bending drive 27 can also be coupled with a coupling that can be moved in the direction of the swivel axis 21 between the control elements 24 and the piston 26 and whose length is dimensioned in such a way that it can be arranged between one or more, or maximally all control elements, on one hand 24, and the piston 26, on the other hand. It is also conceivable to provide a shaft like component for coupling the control elements 24 and the piston 26 whose axial direction runs parallel to the swivel axis 21 and which has shaft sections one after another in that direction that are assigned to different control elements 24 and in the circumferential direction of the shaft, radial projections staggered to one another, whereby depending on the rotational setting of the shaft to its axis, a different number of shaft sections is effective, and so a different number of control elements 24 is connected to the piston 26 by radial shaft projections.~~

~~The ratios on the holding down device 15 are like those on the bending cheek 14. A coupling part 28 is assigned to each segment of the holding down device 18. By means of a setting device, also not shown, the couplings 28 can be engaged or disengaged individually between the segments of the holding down device 18 and the piston 29 of the drive of a holding down device 30. The segments of the holding down device 18 can move linearly in the direction of movement of the piston 29 on a holding down device carrier 31. Corresponding to couplings 25, couplings 28 can be replaced by structurally different components to produce a drive connection between the piston 29 of the drive of the holding down device 30 and the segments of the holding down device 18.~~

~~The initial situation before the sheet metal 6 starts being machine bent is shown in Figure 2. The sheet metal shown in dashes 6 lies on the workpiece support 16. The bending cheeks 14 and the bending cheek segments 17 are in their starting position. The holding down device 15 and the segments of the holding down device 18 are pulled back off the sheet metal 6. The couplings 25, 28 are engaged. There is therefore no drive~~

~~connection between the segments of the bending cheeks 17 and the bending drive 27 and no drive connection between the segments of the holding down device 18 and the drive of the holding down device 30.~~

~~To prepare for the bending process, a number of couplings 25, 28 consistent with the length of the fold being made is engaged between the piston 26 of the bending drive 27 and the control elements 24 or between the segments of the holding down device 18 and the piston 29 of the drive of the holding down device 30.~~

~~In the example shown, two couplings 25, 28 are taken from their off position in Figure 2 into their on position in Figure 3.~~

~~Now, if the piston 26 of the bending drive 27 and the piston 29 of the drive of the holding down device 30 are pushed in the direction of arrows 32, 33, the two couplings 25 engaged come to lie on the two assigned control elements 24 and the two couplings 28 engaged come to lie on the two accompanying segments of the holding down device 18. Thus, the two segments of the holding down device 18 are connected to the drive of the holding down device 30, and the two control elements 24 and with them the two accompanying segments of the bending cheeks 17 are connected to the bending drive 27. The operating mode shown in Figure 4 exists.~~

~~Starting from these conditions, if the drive of the holding down device 30 is activated, the segments of the holding down device 18 previously activated, i.e., connected to the drive of the holding down device 30 drop down onto the sheet metal 6. As a result of positioning the sheet metal 6 in relation to the bending station 8, the activated segments of the holding down device 18 with their projecting ends come to lie in that area of the sheet metal 6 in which the flat groove 13 to be folded connects to the remaining sheet metal 6 (Figure 5). Because of the compressive pressure applied by the drive of the~~

~~holding-down device 30, the sheet metal 6 is secured between the working segments of the holding-down device 18 and the workpiece support 16 against any movement.~~

~~Now, if the piston 26 of the bending drive 27 leaves its position in Figures 4, 5 and moves in the direction of arrow 32, the two activated control elements 24 are moved up on the figures. The accompanying segments of the bending cheeks 17 with their drive arms 20 thus slide along the tracks 23 of the two control elements 24. The two activated segments of the bending cheeks 17 consequently swivel on the swivel axis 21 and bend the groove 13 of the sheet metal 6 upward, as shown in Figure 6 with their bending arms 19. Thus, the desired fold is made, and the bending tool 9 can be sent back to its initial position in Figure 2 by a return stroke of the pistons 26, 29 and corresponding return movements of the bending cheek elements 17 and segments of the holding-down device 18 used for tooling the workpiece.~~

~~A bending tool 9a shown in Figures 7a to 7d and 8a to 8d differs from the bending tool 9 in Figures 2 to 6 basically in terms of the activation and operation of bending cheek 14a. Thus, to activate and deactivate swivel lever-type segments of the bending cheeks 17a, a switching device 34 in the form of a regulating cylinder is used. Thus each segment of the bending cheeks 17a has its own regulating device 34 assigned to it.~~

~~Segments of the bending cheeks 17a that are to be used in subsequent machine tooling are pushed into a receptacle 35 on a driver 36 of a bending drive 27a by the switching device 34 on one drive arm 20a. If the driver 36 is then pushed out of its starting position in Figure 7a into its end position in Figure 7d, it takes the drive arm 20a or the bending cheek segment or segments 17a with it. As a result, the segments of the bending cheeks 17a in question swivel on their swivel axis 21 and deform the sheet metal 6 by means of a bending arm 19a in the way desired. Segments of the bending cheeks 17a that are not used when the sheet metal 6 is tooled are pushed out of the receptacle 35 on~~

~~the driver 36 of the bending drive 27a by the respective switching device 34 or kept in the disengaged position. As shown in Figures 8a to 8d, the driver 36 is then pushed horizontally without the disengaged segments of the bending cheeks 17a swiveling on the axis 21 or the sheet metal 6 being deformed.~~

~~A double tool 37 shown in Figure 9 includes two bending tools 9 that correspond to one another in design and function and are arranged 180° from one another. On one and the same side of the sheet of metal 6 being machined therefore are a holding down device 15 of the one bending tool 9 and a bending cheek 14 of the other bending tool 9. Because of this design, folds can be made in opposite directions on the bending tools 9. A groove of sheet metal 6 folded under is shown in Figure 9.~~

~~Couplings 25, 28 can be used on both sides of the sheet metal 6 optionally to activate a bending cheek 14 or to activate a holding down device 15. Depending on which bending tool part is activated, a hydraulic drive works as a bending drive 27 with piston 26 or as the drive of a holding down device 30 with piston 29.~~

~~In Figure 10, the bending station 8 is integrated into a mechanical arrangement 38 for machining sheet metal 6 that also includes a mechanical cutting device 39 for machine cutting the sheet metal 6. The cutting device 39 is a punch in the example shown. Other conceivable examples are water, a plasma and/or laser cutting devices. With the cutting device 39, first the grooves on three sides are cut free on the flat sheet metal 6. Then, the sheet metal 6 is positioned with the coordinate guide 5 opposite the bending station 8 in such a way that the flat grooves can be folded as shown by the bending station 8.~~

~~The machine functions are CNC controlled on all the machine tooling devices described above.~~

~~Patent Claims~~

~~1. A mechanical bending device for bending flat workpieces, especially sheet metal (6), with at least one bending tool (9, 9a), which has at least one tool part that can be moved by means of a bending drive (27, 27a), wherein the workpiece can be bent along a bending line (11) by being acted on by the part of the tool that moves, and the movable part of the tool includes segments of the tool parts one after another in the direction of the bending line (11), characterized by the fact that at least one segment of the tool part can be connected optionally to the bending drive (27, 27a).~~

BACKGROUND

This invention relates to a method and apparatus for determining the length of at least one of two legs of a part, which legs have been bent toward each other by means of a bending tool at a bending angle whose vertex is at the point of intersection of the straight, angle defining projections of the legs of the bent part, with one end of the leg to be measured delimiting the latter on the far side opposite the vertex of the bending angle. The invention further relates to a method and a device for bending workpieces utilizing the aforementioned method and apparatus for determining the length of the leg of a bent part.

Excluding the bending angle, the length of the legs is the most important functional measure of a bent part. The conventional method heretofore used to determine the length of a leg of a part bent in a bending machine has been to take the part out of the bending machine and measure it manually. The accuracy of that measurement of the length is compromised primarily by the fact that, at the apex of the bent part, the legs

that are to be measured do not meet in an ideal, straight line but instead converge in an arcuate contour or radiused fashion. Thus, the vertex of the bending angle does not really constitute one of the end points of the leg of a bent part and the point of intersection of the straight projections of both legs. Therefore, it is not possible, for instance, to directly gauge the vertex of the bending angle within the determination of the length of the leg of a bent part. Particular difficulties that can be overcome only by means of complex metrology are encountered in the case of open bending angles, i.e., included angles of more than 90°.

It is an objective of this invention to provide apparatus that permits an automated and highly accurate determination of the length of the legs of bent parts with a particular view to the optimization of the workpiece bending processes.

Another objective is to provide a method which accurately and quickly measures the length of the legs of the bent parts.

SUMMARY OF THE INVENTION

It has now been found that the foregoing and related objects can be readily attained in a method for determining the length (b) of at least one of two legs (13, 14) of a workpiece (12), which have been bent toward each other by means of a bending die (6) at a bending angle (ß) whose vertex (S) is located at the point of intersection of the straight, angle forming projections (29, 30) of the legs (13, 14) of the bent part (12), with one end (E) of the leg (13, 14) to be measured limiting the latter on the far side opposite the bending angle vertex (S). The method includes the steps of (a) holding the

object part (12) in the bending die (6); (b) determining the position of the bending angle vertex (S) and the position of the end (E) of the leg (13, 14); and (c) from the respective position of the bending angle vertex (S) and of the end (E) thus determined, calculating the length (b) of the leg as the distance between the bending angle vertex (S) and the end (E).

The position of the bending angle vertex (S) is determined by initially determining the bending angle (ß). During the step of determining the position of the bending angle vertex (S), the workpiece (12) is supported on a backing surface (27,28) and the position of the bending angle vertex (S) is determined on the basis of the position in which the workpiece (12) is supported on the backing surface (27, 28).

Preferably, the position of the bending angle vertex (S) is determined by measuring the bending angle (ß) by optical means and the position of the end of the leg (13,14) of the workpiece (12) is determined by optical means.

In a method for bending workpieces wherein two angular legs (13, 14) of a workpiece are bent toward each other in a bending die (6) at a bending angle (ß) to produce a bent workpiece (12), the length (b) of at least one of the said legs (13, 14) is determined with a bending angle vertex (S) located at the point of intersection of the straight projections (29, 30) of the legs that form the angle (ß) of the legs (13, 14) of the workpiece (12) and with the end (E) of the leg (13, 14) delimiting the latter on the far side from the bending angle vertex (S). The actual value obtained as a result of the determination of the length (b) of a leg (13, 14) is compared to a leg length set point

value and from the result of said actual value/set point value comparison is used to define at least one parameter of significance for the length (b) in a subsequent bending step.

The control apparatus includes (a) a system (31) for determining the position of the bending angle vertex (S), (b) a unit (34) for determining the position of the end (E), and (c) an evaluation unit (36), the system (31) and unit (34) permitting the determination of the position of the bending angle vertex (S) and the position of the end (E) of a bent workpiece (12) held in the bending die (6) in a defined position, and the evaluation unit (36) processes data on the position of the bending angle vertex (S) and of the end (E) to determine the length (b) as the distance between the bending angle vertex (S) and the end (E).

Preferably, a retaining element is provided for the determination of the position of the bending angle vertex (S) and the determination of the position of the end (E), with the workpiece (12) being held in specifically defined fashion in the bending die (6). The system (31) for determining the position of the bending angle vertex (S) includes a unit (9) serving to measure the bending angle (ß) as well as a processor that connects to the unit (9) measuring the bending angle (ß) and to the evaluation unit (36). The processor (32) determines the position of the bending angle vertex (S) on the basis of the bending angle (ß) thus measured. The system (31) for determining the position of the bending angle vertex (S) includes a processor (32) connected to the evaluation unit (36), and a backing surface (27, 28) supporting the workpiece (12) for the determination of the position of the bending angle vertex (S). The processor (32) determines the position of

the bending angle vertex (S) on the basis of the position of the support for the workpiece (12) on the backing surface (27, 28).

Preferably, the unit measuring the bending angle (ß) is an optical measuring tool. The detection and acquisition unit serving to capture the position of the end (E) may include a tactile contact sensor assembly that can be brought into contact with the end (E). This contact sensor assembly in contact with the end (E) is capable of moving with the end (E) during the bending process. Desirably, the contact sensor assembly comprises a positioning stop lug (17, 18) for the workpiece to be bent.

Preferably, the detection and acquisition unit (20, 21) serving to capture the position of the end (E) is an optical image acquisition unit (20, 21).

Ideally, the detection and acquisition unit (34) serving to capture the position of the end (E) is constituted of a positioning stop (17, 18) of the bending device against which the workpiece can be set for appropriate positioning relative to the bending die (6) prior to being processed. The positioning stop (17, 18) is preferably movable by the control system (11). By including an evaluation unit (36) as a part of a system controller (11) in which at least one set point value for the length (b) is stored and by means of which an actual length value can be compared against a length set point value, and, on the basis of the result of the actual versus set point length comparison, at least one parameter controlling the length (b) in at least one subsequent bending operation can be defined.

As can be readily appreciated, the bent part that is to be measured remains in the bending tool where it is held in a particular, defined position. To obtain as accurate a measurement as possible, the length of the leg of interest is measured not directly but by way of the position of the angular vertex and the position of the end of the leg. The position of the vertex of the bending angle is used as the intersection, really nonexistent, of the linear projections of the converging legs of the object part.

The bent part to be measured is retained in the bending tool and held in a defined position. In terms of hardware, this procedural aspect is accomplished by means of the retaining element described herein. In a preferred design version of the bending device according to the invention, however, the bending tool itself serves as the retaining element for the defined positioning of the object part.

An advantageous configuration of the invention determines the position of the vertex of the bending angle is determined by establishing the degree of the bending angle. The bending angle can be established in various ways. For example, it can be physically measured. Alternatively, it can be computed by a so-called "bending formula" stored in a system control unit, and the bending formula describes the bending angle as a function of workpiece and tool related parameters.

The length of the leg is determined by supporting the object part on a backstop and the position of the angular vertex is determined on the basis of the position of the bent part relative to that backstop. In the same way as the bending angle, the support position of the bent part relative to the backstop serves as a basis, attainable with the

necessary degree of accuracy and with conventional means, for establishing the position of the vertex of the bending angle. Therefore, the apparatus embodying this invention is equipped with a processor that connects to an evaluation unit and with a backstop that supports the bent part to permit the determination of the vertex of the bending angle. The processor computes the position of the vertex of the bending angle on the basis of the support of the object part relative to the backstop. In a preferred configuration of the bending device according to this invention, the bending tool serves as the backstop supporting the bent part for the determination of the position of the bending angle vertex.

Preferably, the present invention provides for the use of non-contact and in particular optical determination of the bending angle and/or the position of the vertex of the bending angle. Possible ways for implementation include the split-beam method, i.e. the use of a split-beam system. As an alternative or in addition, tactile methods and systems may be used.

As an example, the measuring system is a contact-sensing unit which can be set against the end of the leg for determining the length of the leg. That contact sensor may be movable to allow it to follow the end of the leg as it is in motion. In particular, the positioning stop for the workpiece to be bent can be used to hold the contact sensor.

Desirably, the bending device uses a positioning stop which serves to keep the workpiece to be processed in position relative to the bending tool, and holds the contact sensor of the measuring unit for the purpose of determining the position of the end of the leg. The positioning stop may also serve to hold a non-contact and especially optical

sensing unit for determining the position of the end of the leg. Preferably, the positioning stop can be moved by the control system.

In a preferred bending method and bending device, the actual result of the measurement of the length of a leg is compared with a predefined length set point value, and the result of this actual value/set point value comparison is used to define at least one length related parameter for at least one subsequent bending step. One such parameter to be defined would be the distance at which positioning stops for the workpiece to be bent need to be set relative to the bending line defined by the bending tool. Subsequent bending steps may involve other workpieces or the same workpiece whose angular length had been determined as the basis for the subsequent parameter definition. Significantly, this invention makes it possible in the case of bent parts with multiple bends to define the parameters of the individual bending operations on the basis of each respectively preceding actual length versus set point value comparison in such a fashion that the sum of the individual leg lengths matches the overall production tolerance specified for the bent part.

BRIEF DESCRIPTION OF ATTACHED DRAWINGS

Figure 1 is a diagrammatic side elevational view of a computer-controlled bending machine embodying the present invention including a bending die and a rear stop system;

Figure 2 is a perspective view of the rear stop system of the bending machine of Figure 1 drawn to an enlarged scale;

Figure 3 is a schematic illustration showing the configuration of the bending die assembly of the bending machine of Figure 1 with a workpiece disposed therein; and

Figure 4 is a schematic illustration of part of the numerical control system for the bending machine of Figure 1.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENT

As shown in Figure 1, a bending machine generally designated by the numeral 1 for sheet metal processing encompasses a machine frame 2 on which a bending beam 3 is guided for movement in an up and down direction. A hydraulic drive unit 4 serves to move the bending beam 3. Mounted on the bending beam 3 is the top element 5 of a bending tool assembly and in the form of a bending die 6. Matching the top element 5 is a bottom die 7 that is supported on a machine platen 8. A tactile bending angle sensor unit 9 is integrated into the top element 5 of the bending die 6. In terms of its design and functionality, the bending angle sensor unit 9 corresponds to the system described in United States Patent No. 5,842,366. Mounted on the far side of the bending die 6, i.e., away from the operator of the bending machine 1, is a rear stop system generally designated by the numeral 10. Located on the opposite side is a system control unit in the form of a CNC controller generally designated by the numeral 11. In the operating state illustrated in Figure 1 a beveling or bending process is completed by bending a workpiece generally designated by the numeral 12 so as to produce the angular sides or legs 13 and 14. As shown in Figure 1, the workpiece 12 to be bent is held with a defined orientation between the top element 5 and the bottom die 7.

Figure 2 shows in detail that the rear stop system 10 encompasses two backstops generally designated by the numerals 15, 16, with the backstop 15 including a stop lug generally designated by the numeral 17, and backstop 16 having a stop lug generally designated by the numeral 18. These stop lugs 17, 18 constitute the positional stops for the flat workpiece that is to be bent and are independently adjustable in all three spatial directions. The movement of the stop lugs 17, 18 is controlled by the CNC controller 11. Underneath a workpiece support 19 of the stop lug 17 is equipped is mounted a camera 20. In corresponding fashion, underneath the work support 21 the stop lug 18 is equipped with a camera 22. The arrows in Figure 2 indicate the directions in which the stop lugs 17, 18 can be moved.

As shown in Figure 3, the bending die 6 is symmetrically configured in terms of the bisector 23 of an angular groove 24 in the bottom die 7. The bisector 23 of the angular groove 24 coincides with the line bisecting the bending angle ß that is formed between the legs 13, 14 of the workpiece 12. Accordingly, the size of the angle between the bisector 23 and each of the legs 13, 14 of the bent workpiece 12 is ß/2. The tip 25 of the top element 5 strikes the upper surface of the workpiece 12 along a bending line 26. The lower surface of the workpiece 12 sits on the sides 27, 28 of the angular groove 24 of the bottom die 7 that forms the backing support for the workpiece 12. In Figure 3, A1 and A2 represent the points of linear support of the workpiece 12 by the sides 27, 28 of the angular groove 24 of the bottom die 7.

As can be clearly seen in Figure 3, the sides, i.e., the legs, 13, 14, of the bent workpiece 12 do not meet in ideal sharp angle fashion but along a radius at the point of their convergence. A straight projection 29 of the leg 13 and a straight projection 30 of the leg 14 intersect at a bending angle vertex S which, in the direction of the bisector 23, is located underneath the bent part 12. The length b of leg 13 extends between the vertex S and one end E of the leg.

For simplicity's sake, the bending angle contact sensor unit 9 which is integrated in the top element 5 of the bending die 6, has been omitted from Figure 3. In traditional fashion, the bending angle sensor unit 9 may include two feeler disks of different diameters (not shown), which, when in operation, are in a symmetrical position relative to the bisector 23 and are in snug contact with the two legs 13, 14 of the workpiece 12. As another essential component, the bending angle sensor unit 9 includes a diagnostic processor (not shown) that determines the bending angle ß on the basis of the difference between the radii of the two feeler disks and of the distance of the feeler disk center points in the direction of the bisector 23. In other words, the bending angle sensor unit 9 is a system that serves to determine the bending angle ß.

As shown in Figure 4, the bending angle sensor unit 9 is part of a processor system 31 for determining the position of the bending angle vertex S. The bending angle sensor unit 9 is connected to a processor 32 that has access to a memory module 33 in which the direction of the bisector 23 of the angular groove 24 in the bottom die 7 and the position of the support points A1, A2 on the sides 27, 28 of the groove 24 as a

function of the bending angle ß are stored. The sides 27, 28 of the angular bottom die groove 24 are thus a contributing feature of the system 31 for determining the position of the bending angle vertex S.

Based on the bending angle ß determined by the bending angle sensor unit 9, the processor 32 calculates the angle ß/2 under which extends the straight projection 29 of leg 13 of the workpiece 12 relative to the bisector 23 of the angular bottom die groove 24. From the angle ß/2, the position of A1 and the direction of the bisector 23, the processor 32 now determines the position of the bending angle vertex S as the intersection of a straight line, touching the side 27 of the angular groove at A1 and extending under the angle ß/2 opposite the bisector 23, with that bisector 23.

Also illustrated in Figure 4 is a unit 34 for determining the end E of the leg 13, which unit includes the backstop 15 of the rear stop system 10 as well as the camera 20 which is mounted on the stop lug 17 of the backstop 15. The camera 20 serves as an image acquisition unit for capturing the position of the end E of the leg 13. The image acquired by the camera 20 of the end E is transferred to a processor 35 as electronic signals. The backstop 15, i.e., its motion control, is also connected to the processor 35. Since the camera 20 occupies a specific position on the stop lug 17, the position of the stop lug 17 determines the position of the camera 20. The positional information thus obtained and the signals emanating from the camera 20 allow the processor 35 to determine the position of the end E of the leg 13.

Using the stop lug 17 as a mount for the camera 20 is particularly desirable given the fact that, at the time at which the position of the end E is to be determined, the stop lug 17 is idle and thus freely available. The stop lug 17, i.e., its workpiece support 19, is used only at the beginning of the bending process, when the flat workpiece that is to be bent is positioned relative to the bending die 6 by being moved against the workpiece support 19 and, if necessary, against the workpiece support 21 of the stop lug 18. The stop lugs 17, 18 that serve as positioning stops ultimately define the direction of the bending line on the workpiece. During the beveling or bending process, the initially flat workpiece is lifted off the stop lugs 17, 18. Thus, for instance, the leg 14 of the workpiece 12, produced among others during the bending process, will be positioned above and at a distance from the stop lugs 17, 18, so that the latter are freely movable once the bending process has been initiated. In view of their triaxial movability, the stop lugs 17, 18 can occupy any spatial position and are thus able to move the camera 20 into any desired position. In particular, to avoid for instance parallactic errors, it is possible to orient the camera 20 in a viewing direction perpendicular to the end E of the leg 13. In addition or as an alternative to the camera 20, the camera 22 may be mounted on the backstop 16 as another image acquisition unit for the optical detection of the position of the end E. In that case the processor 35 will also access the motion control of the backstop 16.

Based on the position of the bending angle vertex S determined by means of the system 31 and the position of the end E of the leg determined by means of the unit 34, an

evaluation unit 36, employing vectorial distance measuring techniques, calculates the length b of the leg as the distance between the bending angle vertex S and the end E. The actual linear length thus determined is compared in a comparator unit 37 with the predefined set point length stored in that unit. If the actual length deviates from the set point value for the length of the leg, that deviation is processed in a compensation module 38. In the machine illustrated, the compensation module 38 activates a servo drive 39 in the rear stop system 10.

In the event that bends are to be produced consecutively on different workpieces based on the same length set point values and the measured length b turns out to be shorter than that set point value, corresponding activation of the servo drive 39 will retract the rear stop system 10 relative to the bending die 6 by the amount determined in the compensation unit 38. If several bends are to be produced in the same workpiece, it is possible, for instance, in the case of a length deviation of the actual value detected on the first bend relative to the set point value, to take that into account in the setting of the rear stop system 10 for the second bending process. In this fashion it is possible to automatically ensure that the sum of the bends produced remains within the predefined overall tolerance.

The bending machine 1 also permits a positional determination of the bending angle vertex S and of the end E by a method different from that described above. For example, the bending angle ß may also be calculated using a bending formula stored in the CNC controller 11. That bending formula describes the bending angle ß as a

function (i) of the geometry of the top element 5 and the bottom die 7, (ii) of the rigidity of the material, (iii) of the thickness of the blank to be bent, and (iv) of the depth of penetration of the top swage 5 into the bottom die 7. However, non-contact optical sensors may be used in lieu of the tactile bending angle sensor unit 9 in determining the bending angle ß. To that effect, one could mount at least one of the cameras 20, 22 on the rear stop system 10. Conversely, the position of the end E can be measured using a tactile contact sensor unit. For example, at least one of the stop lugs 17, 18 may follow the end E in constant contact with the latter throughout the bending process. The position of the stop lug(s) 17, 18 would define the respective position of the end E.

Finally, it is possible to determine the position of the bending angle vertex S and/or the position of the end E by the so-called split beam method. The split beam method and its technical implementation are described for instance in German Patent No. 43 12 565 A1. In that case, at least one of the cameras 20, 22 of the rear stop system 10 may be positioned at a so-called triangulation angle to detect a light trace generated on the part 12 being bent.

Apart from making corrections for subsequent processing cycles, determining the length b of the legs can also serve to check the bent part 12 for deviations from its nominal three-dimensional geometry. For example, in the case of longer beveled parts the length b of the leg may be measured at several points along the bending line 26. An examination of the angle of the bent part 12 is equally feasible. The measurements

obtained can in all cases be recorded automatically. If desired, the results of the corrections made by the compensation module 38 may be visually displayed.

Thus, it can be seen from the foregoing detailed description and the attached drawings that the method and apparatus of the present invention enable automated and accurate determination of the length of the legs of a workpiece being bent.

CLAIMS

Having thus described the invention, what is claimed is:

1. A method for determining the length (b) of at least one of two legs (13, 14) of a workpiece (12), which have been bent toward each other by means of a bending die (6) at a bending angle (ß) whose vertex (S) is located at the point of intersection of the straight, angle forming projections (29, 30) of the legs (13', 14) of the bent part (12), with one end (E) of the leg (13, 14) to be measured limiting the latter on the far side opposite the bending angle vertex (S), comprising:

(a) holding the object part (12) in the bending die (6);

(b) determining the position of the bending angle vertex (S) and the position of the end (E) of the leg (13, 14); and

(c) from the respective position of the bending angle vertex (S) and of the end (E) thus determined, calculating the length (b) of the leg as the distance between the said bending angle vertex (S) and the said end (E).

~~2.~~ ~~The mechanical bending device in Claim 1, characterized by the fact that a swiveling bending tool is provided as the bending tool (9, 9a) with a movable tool part in the form of a bending cheeks (14, 14a) that can swivel on a swivel axis (21) running in the direction of the bending line (11) and by the fact that the bending cheeks (14, 14a)~~

~~contain segment of the tool parts in the form of segments of the bending cheeks (17, 17a), at least one of which can be optionally connected to the bending drive (27, 27a) and can be swiveled on the swivel axis (21) when the drive connection is made, and there is bending action on the workpiece.~~

2. The method for determining the length of at least one of two legs of a workpiece in accordance with Claim 1 wherein the workpiece (12) is retained in the bending die (6) in a defined position.

~~3. The mechanical bending device in one of the preceding claims, characterized by the fact that at least one segment of the bending cheeks (17, 17a) is designed as a two arm swiveling lever with a bending arm (19, 19a) provided on one side of the swivel axis (21) for acting on the workpiece and bending it, and with a drive arm (20, 20a) provided on the other side of the swivel axis (21), for optionally connecting the drive to the bending drive (27, 27a).~~ 3. The method for determining the length of at least one of two legs of a workpiece in accordance with Claim 1 wherein the position of the bending angle vertex (S) is determined by initially determining the bending angle (ß).

4. The method for determining the length of at least one of two legs of a workpiece in accordance with Claim 1 wherein, during the step of determining the position of the bending angle vertex (S), the workpiece (12) is supported on a backing surface (27,28) and the position of the bending angle vertex (S) is determined on the

basis of the position in which the workpiece (12) is supported on said backing surface (27, 28).

5. The method for determining the length of at least one of two legs of a workpiece in accordance with Claim 1 wherein the position of the bending angle vertex (S) is determined by measuring the bending angle (ß) by optical means.

6. The method for determining the length of at least one of two legs of a workpiece in accordance with Claim 1 wherein the position of the end of the leg (13,14) of the workpiece (12) is determined by optical means.

7. A method for bending workpieces wherein two angular legs (13, 14) of a workpiece are bent toward each other in a bending die (6) at a bending angle (ß) to produce a bent workpiece (12), the length (b) of at least one of the said legs (13, 14) is determined with a bending angle vertex (S) located at the point of intersection of the straight projections (29, 30) of the legs that form the angle (ß) of the legs (13, 14) of the workpiece (12) and with the end (E) of the leg (13, 14) delimiting the latter on the far side from the bending angle vertex (S).

8. The method for bending workpieces in accordance with Claim 7 wherein the actual value obtained as a result of the determination of the length (b) of a leg (13,

14) is compared to a leg length set point value and that the result of said actual value/set point value comparison is used to define at least one parameter of significance for the length (b) in a subsequent bending step.

9. Apparatus for determining the length (b) of at least one out of two legs (13, 14) of a workpiece (12) which have been bent toward each other by means of a bending die (6) at a bending angle (ß) whose bending angle vertex (S) is located at the point of intersection of the straight projections (29, 30) of the legs (13, 14) forming the angle (ß) of the legs (13, 14) of the workpiece (12) while an end (E) of the leg (13, 14) concerned delimits the latter on the far side from the bending angle vertex (S), said apparatus including:

(a) a system (31) for determining the position of the bending angle vertex (S);

(b) a unit (34) for determining the position of the end (E); and

(c) an evaluation unit (36), said system (31) and unit (34) permitting the determination of the position of the bending angle vertex (S) and the position of the end (E) of a bent workpiece (12) held in the bending die (6) in a defined position, and said evaluation unit (36) processing data on the position of the bending angle vertex (S) and of the end (E) to determine the length (b) as the distance between the bending angle vertex (S) and the end (E).

10. The apparatus for determining the length of at least one of two legs (13, 14) of a workpiece in accordance with Claim 9 wherein a retaining element is provided for the determination of the position of the bending angle vertex (S) and the determination of the position of the end (E), with the workpiece (12) being is held in specifically defined fashion in the bending die (6).

~~4. The mechanical bending device in one of the preceding claims, characterized by the fact that at least one swivel lever can be engaged by means of a switching device (34) on the drive arm side in a receptacle (35) on a driver (36) of the bending drive (27a) or disengaged from that receptacle (35), whereby the connection between the swivel lever and the bending drive (27a) is made in the engaged mode and is broken in the disengaged mode.~~

11. The apparatus for determining the length of at least one of two legs (13, 14) of a workpiece in accordance with Claim 9 wherein the system (31) for determining the position of the bending angle vertex (S) includes a unit (9) serving to measure the bending angle (ß) as well as a processor that connects to the unit (9) measuring the bending angle (ß) and to the evaluation unit (36), said processor (32) determining the position of the bending angle vertex (S) on the basis of the bending angle (ß) thus measured.

~~5. The mechanical bending device in one of the preceding claims, characterized by the fact that it has a control element (24) with a track (23) between at least one swivel lever and the bending drive (27), whereby the swivel lever is supported on the drive arm side on the track (23) of the control (24), and it can be connected optionally to the~~

~~bending drive on the bending drive side by means of a switching device, whereby when the drive connection is made between the control element (24) and the bending drive (27), the swivel lever is acted on by the control (24) via its track (23) on the drive arm side and can thereby swivel on the swivel axis (21) when there is bending action on the workpiece.~~

12. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 9 wherein the system (31) for determining the position of the bending angle vertex (S) includes a processor (32) connected to the evaluation unit (36), and a backing surface (27, 28) supporting the workpiece (12) for the determination of the position of the bending angle vertex (S), said processor (32) determining the position of the bending angle vertex (S) on the basis of the position of the support for the workpiece (12) on the backing surface (27, 28).

13. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 9 wherein the unit measuring the bending angle (ß) is an optical measuring tool.

14. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 9 wherein the unit (34) serving to determine the position of the end (E) includes a detection and acquisition unit (20, 21) for capturing the position of the end (E), and a processor (35) connected to the detection and acquisition unit (20,21) and also to the evaluation unit (36), said processor (35) determining the position of the end (E) on the basis of the position of the end (E) captured by the detection and acquisition unit (20, 21).

~~6. The mechanical bending device in one of the preceding claims, characterized by the fact that the switching device for optionally connecting the control (24) and the bending drive (27) has at least one coupling part (25) that can be engaged or disengaged between the control (24) and the bending drive (27), whereby the connection between the control (24) and the bending drive (27) is made with the coupling part (25) engaged and broken with the coupling part (25) disengaged.~~

15. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 14 wherein the detection and acquisition unit serving to capture the position of the end (E) may include a tactile contact sensor assembly that can be brought into contact with the end (E).

~~7. The mechanical bending device in one of the preceding claims, characterized by the fact that the bending tool (9, 9a), designed as a swiveling bending tool, has a holding-down device (15) extending along the bending line (11), by means of which the workpiece can be acted on in the transverse direction of its flat extension and can thereby be fixed between the holding-down device (15) and a workpiece support (16) on the side of the workpiece opposite the holding-down device (15), and by the fact that the holding-down device (15) includes segments of the holding-down device (18) one after another in the direction of the bending line (11), at least one of which can optionally be connected to a drive of the holding-down device (30) and can be transferred into a position where it acts on the workpiece by producing a drive connection, whereby when the workpiece is bent, segments of the holding-down device (18) and segments of the bending cheeks (17, 17a) working together at the same time with the drive of the holding-down device (30) or with the bending drive (27, 27a) are connected.~~

16. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 15 wherein the contact sensor assembly that is in contact with the end (E) is capable of moving with the end (E) during the bending process.

~~8. The mechanical bending device in one of the preceding claims, characterized by the fact that at least two bending tools (9) are provided in the form of swivel bending tools, each of which has a bending cheek (14) that can swivel, with at least one segment of the bending cheeks (17) that can be connected optionally to the bending drive (27) and a holding down device (15), whereby the bending cheek (14) of one and the holding down device (15) of the other bending tool (9) are arranged on one and the same side of the workpiece.~~

17. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 15 wherein the contact sensor assembly comprises a positioning stop lug (17, 18) for the workpiece to be bent.

~~9. The mechanical bending device in one of the preceding claims, characterized by the fact that at least on one side of the workpiece, the holding down device (15) has a drive (30), and the bending drive (27) of the one and the drive of the holding down device (30) of the other bending tool (9) have at least one common drive element.~~

18. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 14 wherein the detection and acquisition unit (20, 21) serving to capture the position of the end (E) is an optical image acquisition unit (20, 21).

19. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 9 mounted in a device for bending workpieces including a bending die (6) by means of which at least two legs (13, 14) of a workpiece can be bent toward each other to produce a bent workpiece (12) with a bending angle (ß) whose bending angle vertex (S) is located at the point of intersection of the projections (29, 30) forming the angle (ß) of the legs (13, 14) of the bent workpiece (12), and an end (E) of the respective leg (13, 14) delimiting the latter on the far side opposite the bending angle vertex (S), and, additionally, a system for determining the length (b) of a leg (13,14).

~~10. A mechanical arrangement for machining flat workpieces, especially sheet metal (6), characterized by the fact that at least one mechanical bending device (8) according to one of Claims 1 to 9 and also at least one mechanical cutting device (39) for machine cutting workpieces are provided, whereby workpiece parts can be bent and machine cut by means of the mechanical cutting device (39).~~

~~Abstract~~

20. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 19 wherein the bending die (6) itself serves as the retaining element for the defined placement of the workpiece (12) for the determination of the bending angle vertex (S) and/or for the determination of the position of the end (E).

21. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 20 wherein a backing surface (27, 28) supporting the workpiece (12) for the determination of the position of the bending angle vertex (S) is provided by the bending die (6).

~~A mechanical bending device and a mechanical arrangement with this type of bending device.~~

22. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 21 wherein a contact sensor assembly in the detection and acquisition unit (34) serving to capture the position of the end (E) is constituted of a positioning stop (17, 18) of the bending device against which the workpiece can be set for appropriate positioning relative to the bending die (6) prior to being processed.

~~A mechanical bending device (8) for bending flat workpieces, especially sheet metal (6), has at least one bending tool (9), which includes at least one tool part that can move by means of a bending drive (27). When acted on by the tool part that moves, the workpiece can be bent along a bending line (11). The movable tool part has segments of the tool parts one after another in the direction of the bending line (11), at least one of which can be connected optionally to the bending drive (27).~~

23. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 22 an optical detection and acquisition unit (20, 21) for capturing the position of the end (E) is at least in part mounted on a positioning stop (17, 18) of the bending device.

~~A mechanical arrangement for machining flat workpieces, especially sheet metal (6) includes, besides the mechanical bending device (8) described, a mechanical cutting device. On the mechanical bending device (8), workpiece parts can be bent and machine cut by means of the mechanical cutting device.~~

24. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 23 wherein the positioning stop (17, 18) is preferably movable by the control system (11).

25. The apparatus for determining the length of at least one of two legs (13,14) of a workpiece in accordance with Claim 24 wherein, for determining the length (b) of a leg, there is included an evaluation unit (36) as a part of a system controller (11) in which at least one set point value for the length (b) is stored and by means of which an actual length value can be compared against a length set point value, and, on the basis of the result of the actual versus set point length comparison, at least one parameter controlling the length (b) in at least one subsequent bending operation can be defined.

~~(Figure 2)~~

ABSTRACT

A method and device for determining the length (b) of at least one of two legs (13, 14), of a workpiece (12) bent toward each other at a bending angle (ß) requires location of the workpiece (12) in a defined position. The position of the bending angle vertex (S) and the position of the end (E) of the leg (13, 14) to be measured are determined. Based on the position of the bending angle vertex (S) and of the end (E), the length (b) is calculated as the distance between the bending angle vertex (S) and the end (E). The measuring apparatus includes a system serving to determine the position of the bending angle vertex (S), a unit serving to determine the position of the end (E) and an evaluation unit which, based on the position of the bending angle vertex (S) and of the end (E), calculates the length (b) as the distance between the bending angle vertex (S) and the end (E).

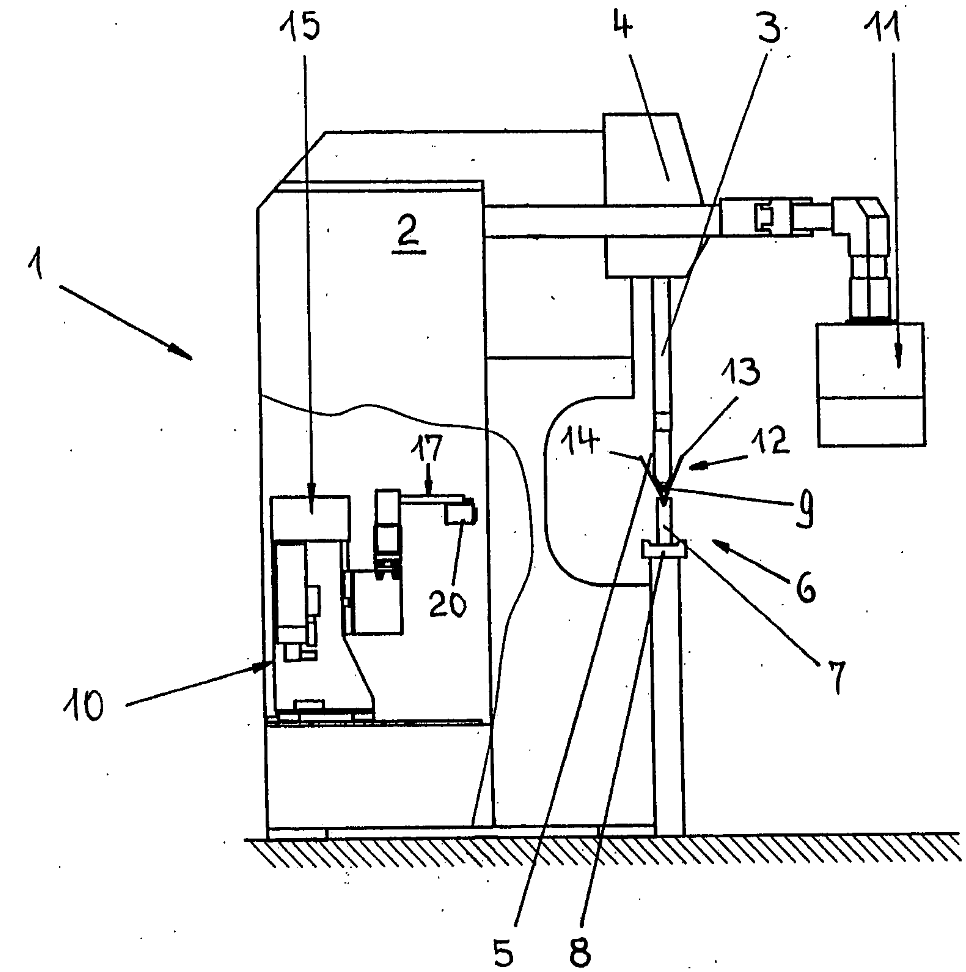

Fig. 1

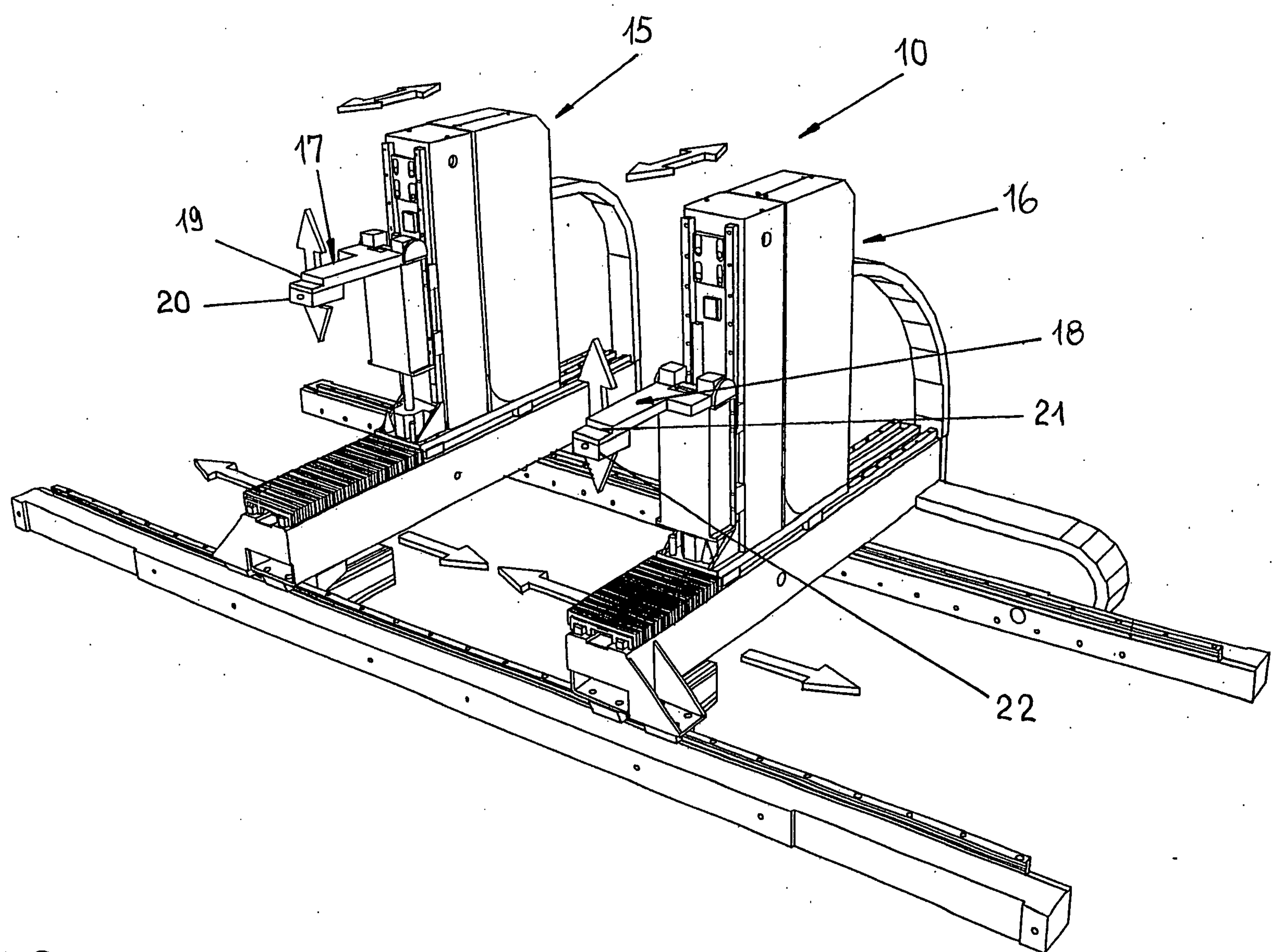

Fig. 2

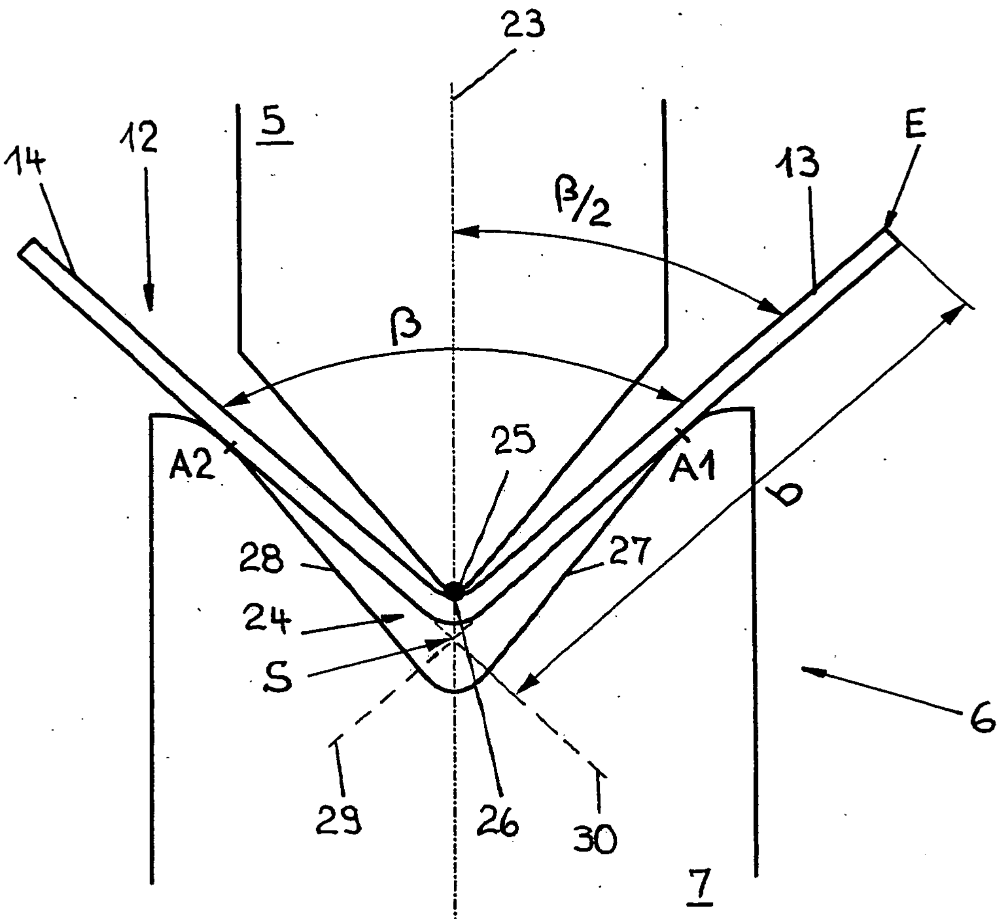

Fig. 3

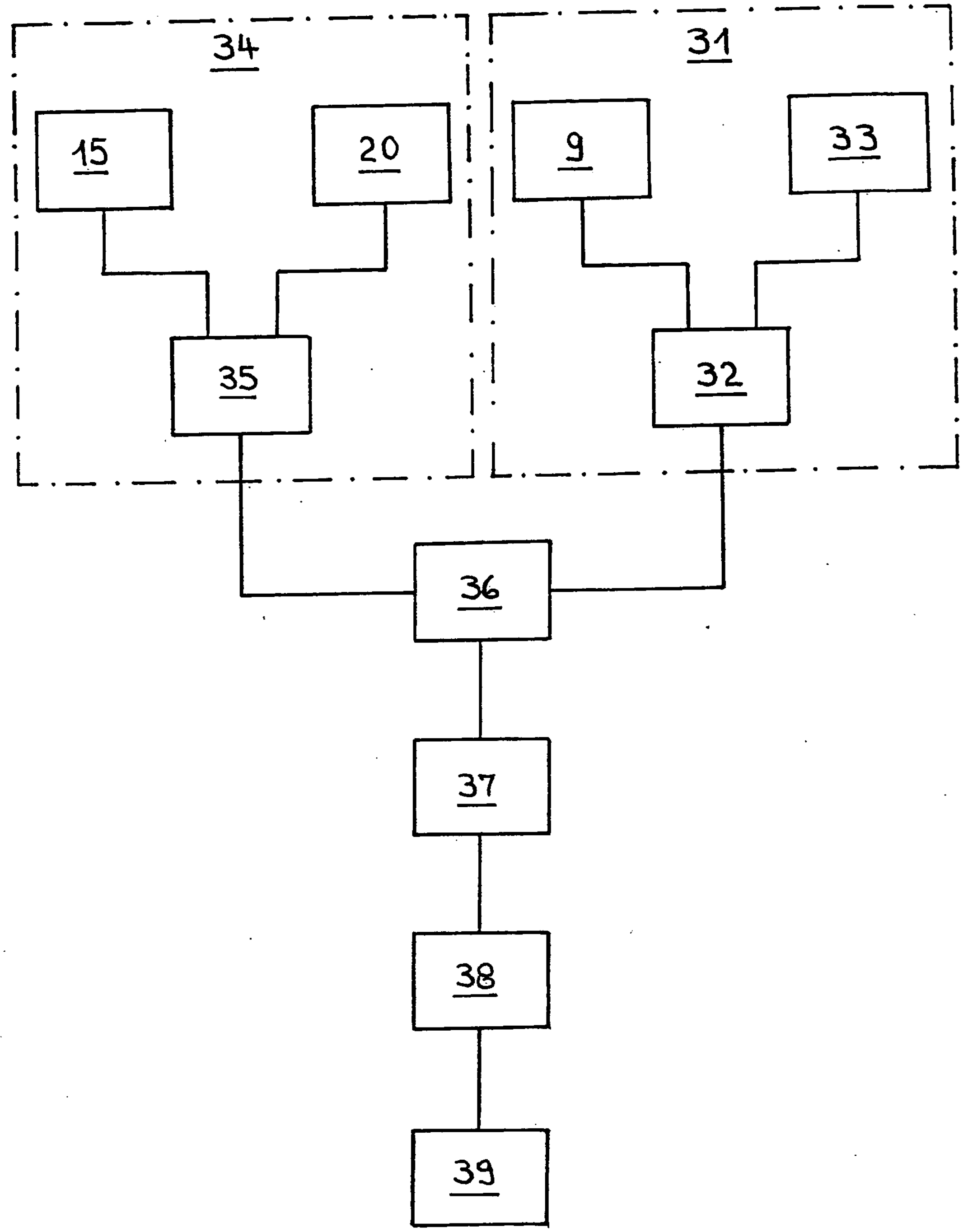

Fig. 4